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FACTORS AFFECTING the NUTRITIVE VALUE of FOODS

Studies at the U. S. Plant, Soil,
and Nutrition Laboratory

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U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

Some important agricultural problems are primarily regional in scope rather than being country-wide or limited to a State. To meet the needs for research on such problems, the Bankhead-Jones Act of 1935 provided for regional laboratories, to be administered by the Secretary of Agriculture, which would mobilize scientific resources for a fundamental attack on some of the most important of these problems.

Nine such laboratories have been established. Each deals with a problem or group of problems selected in cooperation with the State agricultural experiment stations of the region as being among the most important faced by agriculture in that section of the country. The States cooperate with the Department in planning and carrying out the research program of each laboratory on a regional basis. At the same time the subjects under investigation are of importance in varying degrees to all major agricultural regions, so that the results obtained by the laboratories contribute to agriculture on the national and local as well as the regional level.

This publication is one of a series of reports, each of which describes the work of one of the Bankhead-Jones laboratories, covering its program, results obtained to date, and the continuing research. Papers on various phases of the work have been published by all the laboratories as Department publications and in technical journals.

The laboratories and their locations are as follows:

U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C.
U. S. Regional Pasture Research Laboratory, State College, Pa.
U. S. Regional Soybean Laboratory, Urbana, Ill.
U. S. Regional Swine Breeding Laboratory, Ames, Iowa.
U. S. Western Sheep Breeding Laboratory, Dubois, Idaho.
U. S. Regional Animal Disease Research Laboratory, Auburn, Ala.
U. S. Regional Poultry Research Laboratory, East Lansing, Mich.
U. S. Regional Salinity Laboratory, Riverside, Calif.
U. S. Plant, Soil, and Nutrition Laboratory, Ithaca, N. Y.

P. V. Cardon,
Administrator of Agricultural Research.

Cover Illustration—U. S. Plant, Soil, and Nutrition Laboratory, Ithaca, N. Y.

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FACTORS AFFECTING THE NUTRITIVE VALUE OF FOODS

Studies at the U. S. Plant, Soil, and Nutrition Laboratory[1]

Many thoughtful persons have come to believe that substandard diets are contributing causes to a large proportion of the ailments and diseases common to mankind. Some overenthusiastic individuals even believe that improving the diet will eliminate one or all of the health problems involved. Some claim that we eat too much, some that we don't get enough vitamins, and others that we raise our crops on soil not properly fertilized. Certain groups want us to use only organic fertilizers on our soils, while others advocate particular mineral fertilizers, and so on.

The truth is that there is no definite answer so far to the problem of production of food for better nutrition. We need to know much more before we can say what are the best methods of producing food for a perfect diet—if there is such a thing—and how any given diet deviates from the optimum.

The nutritive quality of any diet is influenced by several factors, including food habits, the abundance and nutritive quality of the food supply, education, and economic conditions. We know all too little about how these factors operate and how to modify any one of them to bring about significant improvement. We have much to learn, not only about the influence on nutrition of these factors individually, but about their interrelationships. Progress is being made, but there is still a long way to go.

In many respects our nutrition problems begin with the soil, the basic medium on which all crops are grown, but other factors may have a profound influence on the nutritive value of any given crop. Climate during the growing season, including sunshine and temperature, and the genetic constitution of the plants are also important. Climate can directly affect the quality of the crop, or it may affect it indirectly through its influence on the character of the soil. The nutritive value of a crop consumed by man is of direct importance. The nutritional effect of a crop fed to animals is dual: First, its effect on the health and growth of the animal; second, its effect on the quantity and quality of animal products, such as milk, meat, and eggs, consumed by man. Thus there is a direct line of causation from climate and soil through the nutritional quality of plants to the health of animals and man.

PHYSICAL PLANT, STAFF, AND COLLABORATORS OF THE LABORATORY

The Plant, Soil, and Nutrition Laboratory was established in 1939 by direction of the Secretary of Agriculture. A Memorandum of Understanding was entered into by the United States Department of Agriculture and the agricultural experiment stations of the Northeastern States—Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and West Virginia. The memorandum provided that the laboratory should be national rather than regional in scope and should have a group of collaborators representing all the different regions of the country. The laboratory is a unit of the Agricultural Research Administration of the Department. Relationships with the appropriate bureaus of the Administration are maintained through representatives of the bureaus who are appointed as collaborators.

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[1] Prepared by the staff of the U. S. Plant, Soil, and Nutrition Laboratory, Ithaca, N. Y.

The laboratory functions in close cooperation with Cornell University. It is located on the university campus and is serviced as a part of the Cornell plant. Members of the staff of the College of Agriculture cooperate in the laboratory's activities, and several laboratory scientists have also been appointed to the college faculty. Various facilities of the university are available to the laboratory for its research program.

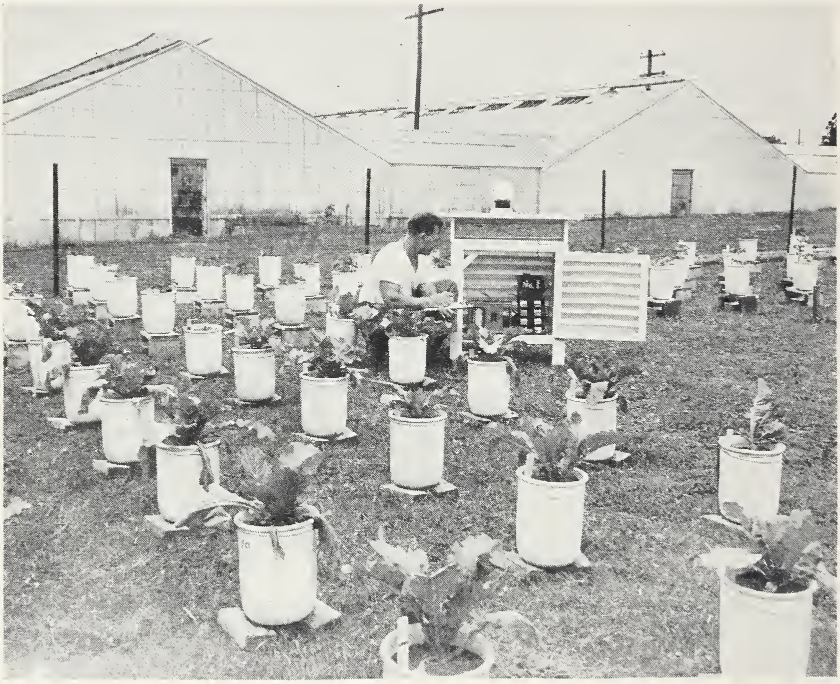

Figure 1.—An integrating light recorder in an experimental plot where turnip plants are exposed to known treatments under controlled conditions. This instrument records the amount of light received daily for a week. The dials are read and the instrument is reset each Monday. Coupled with each light recorder is a hygrothermograph (instrument at left), which records continuously the temperature and relative humidity of the air.

The laboratory buildings, constructed during 1939–41, are located on a plot of approximately 2 acres. They include a four-story brick building and a greenhouse with full basement and a headhouse. The main building contains chemical, physiological, microbiological, and small-animal laboratories and various special laboratories equipped to serve the needs of research in soils, plants, and nutrition. There are rooms for growing plants under controlled conditions of light, temperature, and humidity, and facilities are available for dehydration, quick-freezing, spectroscopy, and microphotography.

To carry out some of their studies, members of the staff have devised special equipment, such as the "integrating light recorder" (fig. 1). Several of these instruments were built to measure the amount of light received by plants growing in fields.

Through cooperative arrangements with Cornell University a large acreage of field plots for soil and agronomic studies and an experimental barn for controlled large-animal feeding and metabolism experiments are provided.

The scientific staff of the laboratory numbers 12 persons, specialists in the various fields in which the laboratory operates. They do not carry on research in their special fields as such but pool their knowledge and techniques in an integrated attack on the over-all objectives of the laboratory.

Once a year the collaborators meet with members of the staff at the laboratory. Results of the work are discussed and suggestions proposed for further research. Those who are now serving as collaborators are:

D. I. Arnon, Division of Plant Nutrition, University of California, Berkeley, Calif.
F. E. Bear, Head, Soils and Crops Department, New Jersey Agricultural Experiment Station, New Brunswick, N. J.
R. W. Cummings, Associate Director, North Carolina Agricultural Experiment Station, State College Station, Raleigh, N. C.
R. A. Dutcher, Head, Department of Agricultural and Biological Chemistry, Pennsylvania State College, State College, Pa.
H. K. Hayes, Chief, Division of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minn.
A. C. Hildreth, Superintendent, Cheyenne Horticultural Field Station, Bureau of Plant Industry, Soils, and Agricultural Engineering, Cheyenne, Wyo.
D. R. Hoagland, Head, Division of Plant Nutrition, University of California, Berkeley, Calif.
Charles E. Kellogg, Chief, Division of Soil Survey, Bureau of Plant Industry, Soils, and Agricultural Engineering, Beltsville, Md.
C. G. King, Scientific Director, The Nutrition Foundation, Chrysler Building, New York, N. Y.
J. E. Knott, Head, Division of Truck Crops, University of California, Davis, Calif.
H. C. McPhee, Assistant Chief, Bureau of Animal Industry, Washington, D. C. (representing the Chief, Bureau of Animal Industry).
H. H. Mitchell, Professor of Animal Nutrition, Department of Animal Husbandry, University of Illinois, Urbana, Ill.
W. H. Pierre, Head, Agronomy Department, Iowa State College of Agriculture, Ames, Iowa.
O. E. Reed, Chief, Bureau of Dairy Industry, Washington, D. C.
W. J. Robbins, Director, The New York Botanical Garden, Bronx Park, New York, N. Y.
R. M. Salter, Chief, Bureau of Plant Industry, Soils, and Agricultural Engineering, Beltsville, Md.
W. H. Sebrell, Surgeon, U. S. Public Health Service, National Institute of Health, Bethesda, Md.
Louise Stanley, Special Assistant to Research Administrator, Agricultural Research Administration, Washington, D. C.
Hazel K. Stiebeling, Chief, Bureau of Human Nutrition and Home Economics, Washington, D. C.

OBJECTIVES AND WORK OF THE LABORATORY

The broad over-all purpose of the laboratory's program is to improve the health and performance of human beings and farm animals by showing how they may be provided with nutritionally superior food and feed. Because malnutrition in this country is caused by foods low in nutritional quality perhaps to a greater extent than by diets inadequate in quantity as measured by calories, our nutrition-education program has stressed the increased use of foods that are good sources of the specific nutrients known to be needed. More recently it has been shown that much can be done to improve the nutritional quality of individual foods as actually consumed.

The possibilities of conserving nutrients in processing, storing, marketing, and cooking have been demonstrated. Much greater improvement in health through better nutrition can be hoped for as we acquire and apply knowledge of methods of improving nutritional quality of our food literally from the ground up. The development of such knowledge is the specific objective of the U. S. Plant, Soil, and Nutrition Laboratory.

The data in the literature suggest wide variations in the nutrient content of a given basic food, be it a seed, a fruit, or a vegetable. These variations are caused by a number of factors. While to some extent they may merely reflect faulty analytical and sampling procedures, to a much greater degree they result from different methods and conditions of production. Genetic as well as soil and climatic factors are involved. In the past, production factors have been studied primarily from the standpoint of improving yield and market quality. Nutritive value has often been neglected. But in addition to yield, nutrient units such as vitamin A or calcium per pound of crop should be considered. The present wide ranges in the nutritive content of many foods as produced indicate clearly the possibility of improving their nutritional quality.

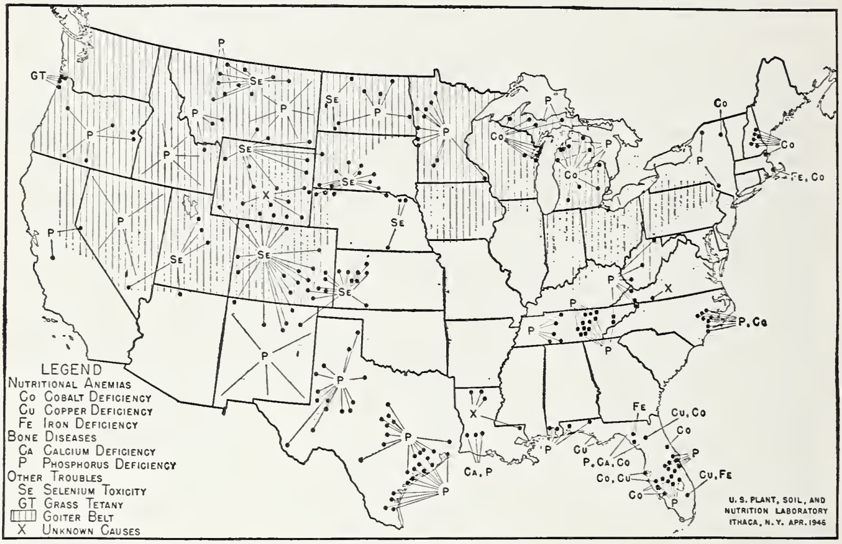

Figure 2.—Known areas in the United States where mineral-deficiency diseases of animals occur. The dots indicate the approximate location of soils with observed deficiencies. The lines not terminating in dots indicate a generalized area where specific locations have not been reported. The goiter region also is a generalized area.

Studies to accomplish the laboratory's objective must recognize that the factors involved are interrelated. The influence of soil variables cannot be definitely ascertained except as climatic and genetic factors are controlled. Results obtained under one set of conditions do not closely resemble those obtained under other sets of conditions. Many basic physiological and biochemical problems arise and must be studied concurrently. The ultimate objective is to provide recommendations for practice which will be effective on farms in all regions. As part of the integrated attack on these problems the laboratory is conducting investigations in cooperation with various State agricultural experiment stations throughout the country, as well as with certain bureaus of the Agricultural Research Administration.

Early in its program the laboratory undertook studies of the occurrence of mineral nutritional diseases of both plants and animals with the ultimate objective of classifying the geographical regions of the United States with respect to the adequacy of supplies of different mineral elements in the soils (fig. 2). Crop-production methods and principles have been studied to learn more about the elaboration in the plant of such critically important nutrients as the vitamins. Animal studies have included investigations of the mineral requirements of animals and the characteristics and symptoms of mineral-deficiency diseases.

Many of the research accomplishments of the laboratory are published in technical bulletins and scientific journals. (See the list of publications beginning on p. 27.) Some of the studies and results are discussed briefly in the following pages.

OCCURRENCE OF MINERAL NUTRITIONAL DISEASES OF PLANTS AND ANIMALS IN THE UNITED STATES

The occurrence of nutritional troubles in either plant or animal is obviously the most reliable indicator of soil deficiencies. Consequently, considerable effort has been made to locate and map the places where such troubles are found and to determine the soil factors associated with them. This is the first step in the classification of geographical regions in the United States with respect to the adequacy of supplies of different mineral elements.

Interest in the distribution of nutritional troubles in plants and animals is a natural sequence to diagnosing and classifying these troubles and their various symptoms. The preparation of maps of nutritional troubles is still a rather difficult undertaking, for although there is much general information concerning their occurrence and relationship to soil characteristics, there are still too few reports specific enough to use in plotting the data on maps. With the information now available, an attempt has been made, however, to indicate in general the areas associated with mineral troubles in either plants or animals (fig. 2). The relatively young, excessively drained soils of the Coastal Plains and the Northeast are those most frequently associated with deficiencies of boron, manganese, copper, zinc, magnesium, cobalt, and phosphorus in both plants and animals (figs. 3 and 4). Extensive areas of alkaline soils in the West are also associated with deficiencies of these elements. Deficiencies of copper in mucks and other soils high in organic matter probably present special problems.

The most widespread deficiency in animals is, no doubt, that of phosphorus. The deficiency of iodine is the only other one widely known at present. There has been an increase, however, in the number of reported observations of deficiencies in cobalt in the last few years. If these are further substantiated, much of the Atlantic Coastal Plain and the Northern States from Wisconsin through New England may become known as cobalt-deficient areas. It is probable, of course, that multiple deficiencies will be established eventually in many of these places.

Cobalt Deficiency

Many problems in breeding and raising cattle and sheep appear to be related to a deficiency of cobalt in forage. In some areas farmers have abandoned any attempt to raise these animals, while elsewhere difficulties constantly develop in one or more animals in a herd.

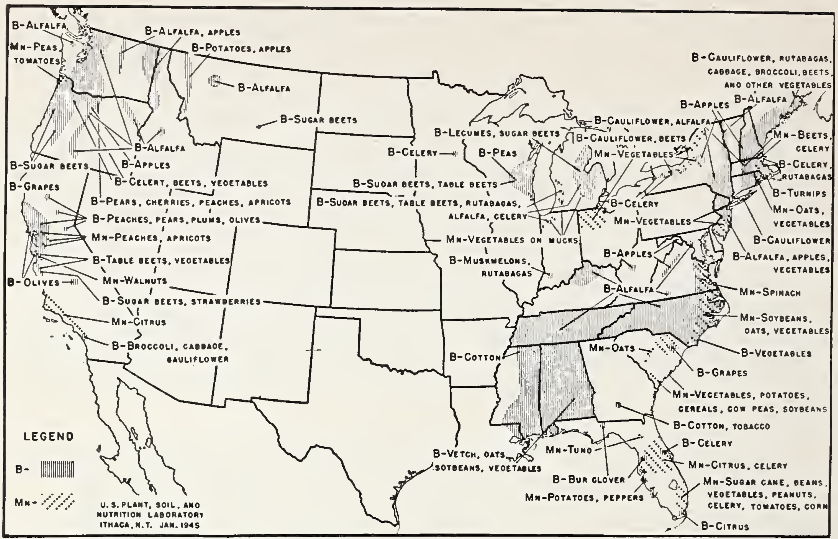
B-Alfalfa
Mn-Peas, tomatoes
B-Alfalfa, apples
B-Potatoes, apples
B-Alfalfa
B-Sugar beets
B-Alfalfa
B-Apples
B-Sugar beets
B-Grapes
B-Celery, beets, vegetables
B-Pears, cherries, peaches, apricots
B-Peaches, pears, plums, olives
Mn-Peaches, apricots
B-Table beets, vegetables
B-Olives
Mn-Walnuts
B-Sugar beets, strawberries
Mn-Citrus
B-Broccoli, cabbage, cauliflower
LEGEND
B-
Mn-
U. S. Plant, Soil, and Nutrition Laboratory Ithaca, N.Y. Jan. 1945
B-Celery
B-Legumes, sugar beets
B-Peas
B-Sugar beets, table beets
B-Sugar beets, table beets, rutabagas, alfalfa, celery
Mn-Vegetables on mucks
B-Muskmelons, rutabagas
B-Cotton
B-Vetch, oats, soybeans, vegetables
B-Cauliflower, rutabagas, cabbage, broccoli, beets and other vegetables
B-Apples
B-Alfalfa
B-Cauliflower, alfalfa
B-Cauliflower, beets
Mn-Vegetables
Mn-Beets, celery
B-Celery, rutabagas
B-Turnips
Mn-Oats, vegetables
B-Celery
Mn-Vegetables
B-Cauliflower
B-Alfalfa, apples, vegetables
B-Apples
B-Alfalfa
Mn-Spinach
Mn-Soybeans, oats, vegetables
Mn-Oats
B-Vegetables
B-Grapes
Mn-Vegetables, potatoes, cereals, cow peas, soybeans
B-Cotton, tobacco
B-Celery
Mn-Tung
Mn-Citrus, celery
B-Bur clover
Mn-Potatoes, peppers
Mn-Sugar cane, beans, vegetables, peanuts, celery, tomatoes, corn
B-Citrus

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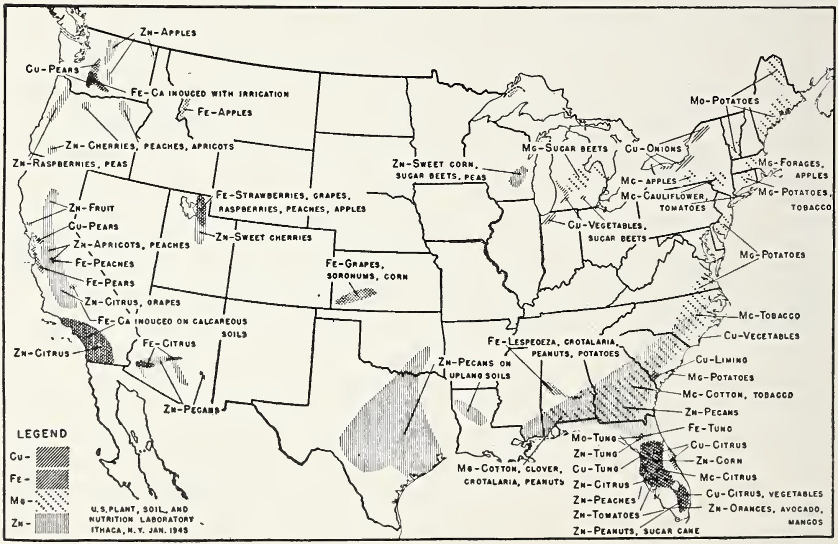
Figure 3.—Location of soils deficient in boron (B) and manganese (Mn) as revealed by limited growth or other symptoms of nutritional trouble in plants. The deficient areas, though necessarily shown as continuous, are actually intermittent.



U S DEPARTMENT OF AGRICULTURE

Figure 4.—Location of soils deficient in copper (Cu), iron (Fe), magnesium (Mg), and zinc (Zn) as shown by limited growth or other symptoms of nutritional trouble in plants. The areas are actually intermittent in character.

Cobalt deficiency was first diagnosed in cattle and sheep in Australia and New Zealand. In those countries ranchers came to recognize certain places as "sick areas." Animals grazing in these areas would become sick, develop anemia, lose their appetite, waste away, and finally die. Sick animals transferred to other areas recovered. It was found that the trouble could be cured by feeding affected animals cobalt salts or by fertilizing the soil with small amounts of cobalt.

Since the discovery of this trouble in Australia and New Zealand, many areas throughout the world have been recognized as cobalt-deficient. From a number of areas in the United States reports have been received of ailing animals being cured with cobalt (fig. 5). The laboratory has been investigating the extent and nature of this cobalt problem for several years.

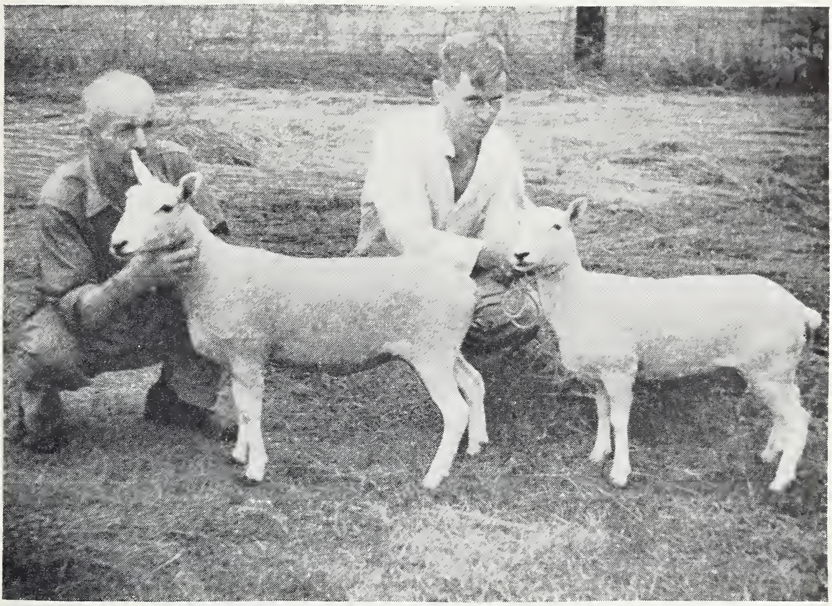


Figure 5.—In areas of borderline deficiencies, a sheep receiving cobalt as a supplement in its ration, as the animal at the left, will grow and gain weight faster than one receiving only locally grown forage, like that at the right. Such deficiencies often cannot be detected except by comparing affected animals with normal ones.

Detailed surveys of troubles in cattle have been started in Lenoir County, N. C., in St. Lawrence County, N. Y., and in New Hampshire, where cobalt appears to be deficient in the forages and in the soil. In North Carolina milk cows in particular are affected, while in St. Lawrence County bulls and calves also seem to require cobalt supplements. Apparently sheep do not thrive at all in parts of St. Lawrence County, and in other parts they do not survive. In both areas samples of soils and forages have been taken in an effort to determine the exact nature of the deficiency and to map the soils and areas involved.

The deficiency seems to be much more widespread than was at first suspected, and it is believed that other deficient areas, as yet unsuspected, will be discovered. As our knowledge of this trouble and the conditions associated with it increases, it will be possible to advise farmers more fully as to the best means of combating it in their cattle and sheep.

FACTORS INFLUENCING VITAMIN CONTENT OF CROPS

Though the products of a certain kind of plant may in general be rich in a particular constituent, the amount of this constituent may vary considerably under different growing conditions. Thus tomatoes generally are considered fairly rich in vitamin C, but it is known that tomatoes of a given variety may have five times as much vitamin C when grown under some conditions as under others. Similar variations could be cited with respect to different nutrients in many food crops. These variations are of great interest to the research scientist, for if he can learn to understand and control the factors responsible for them, he should be able to tell farmers how to produce more high-quality products and thus increase the nutritive value of the general food supply.

It has often been assumed that the nutritive value of any food crop depends entirely on the soil on which the crop is grown and on how the soil is cultivated, fertilized, and irrigated. However, climatic conditions, as represented by light, temperature, atmospheric humidity, and wind movement, are also important, and genetic factors, too, play a vital part in determining the nutritive value of any crop. For example, one variety of tomatoes may have a much higher content of vitamin C than another.

In order to learn more of the causes of these variations in nutritional quality, the several factors known to be important have been studied one by one. For example, plants have been grown in pure nutrient-solution cultures (a method sometimes called soilless growth, or hydroponics) with careful control of the supply of the individual mineral elements which the plant needs for growth. "Synthetic soils," made by saturating resins with mineral nutrients and mixing with sand, also furnish a controlled medium for the growth of plants (fig. 6).

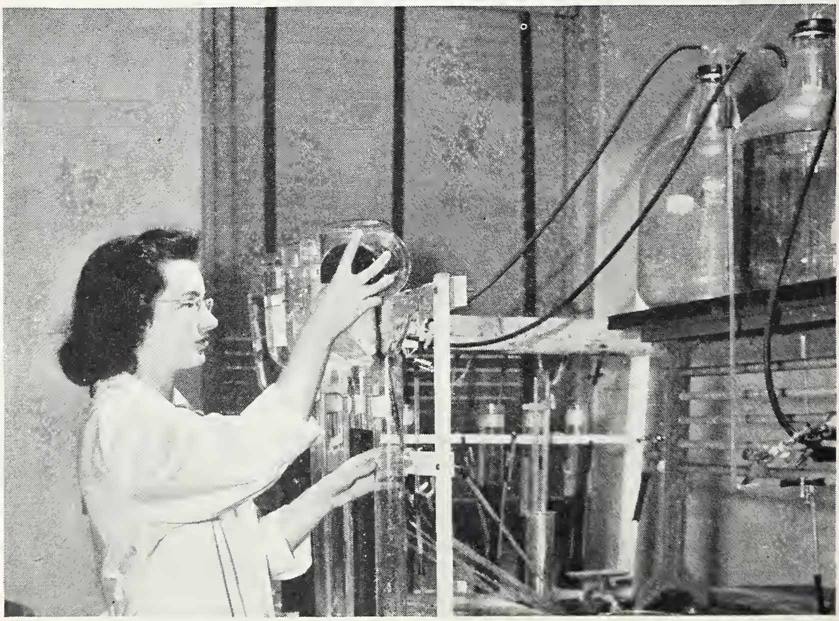


Figure 6.—Preparing "synthetic soil" as an aid to research on the nutrient content of plants. The laboratory worker is saturating synthetic resins with mineral nutrients. These resins are mixed with sand so as to supply different amounts of specific minerals. Plants are then grown on the sand-resin mixtures, which have many of the properties of soil. For research they have the advantage over soil that their composition is known and can be varied at will.

Other experiments involve the use of chambers where artificially produced climatic conditions are closely controlled. Careful studies have also been made of the influence of heredity on nutritive value. Some of the research methods used are discussed in the following pages.

Vitamin C in Tomatoes

Why do tomatoes from different localities vary so much in vitamin C content? It was first assumed, from reports in the literature, that variations in soil-fertility levels and in cultural practices affect the vitamin C value. A series of experiments was conducted in which tomato plants of an inbred variety were grown in pure solution cultures with the supply of each mineral nutrient carefully regulated. Different amounts of the essential mineral elements, ranging from deficient to excessive, were used. At the same time, other plants were grown in soils from various sources, fertilized with different quantities of nitrogen, potash, and phosphate, and analyzed for their vitamin C content.

Laboratory examination of the tomatoes grown under these various soil conditions and with the various mineral elements showed that these treatments had little influence on the vitamin C content of the fruit, although extreme variations in growth of the plants and in yield of tomatoes occurred. In some treatments plants grew so poorly that they ripened only one fruit, while in others the plants produced a full crop of tomatoes; but the vitamin C content of the fruit from all treatments averaged very nearly the same.

Tomatoes of the same variety grown in Wyoming, California, Wisconsin, and New York showed marked differences in vitamin C content; but when soils from those areas were brought to Ithaca, tomatoes grown on them there showed on an average no difference in vitamin C content, regardless of the origin of the soil. It was next observed that plants grown in the greenhouse in the fall and winter produced fruit containing only half as much vitamin C as plants of the same variety grown outside in the summer. Market tomatoes also were found to be low in vitamin C in the winter.

These results indicated, first, that soil factors were probably of minor importance in influencing vitamin C content of tomatoes, and second, that climatic factors associated with season and location were probably of primary importance.

Next an attempt was made to find out which specific factor or factors were involved. Plants were grown in rooms where temperature, humidity, and various light factors could be controlled. By varying one factor at a time it was found that temperature and humidity were of minor importance but that the amount of light seemed to be effective in causing changes in vitamin C level, particularly the amount of light during the period just before harvest. In analyzing turnip greens, for example, more than eight times as much vitamin C was found in a set of plants illuminated by 5,000 foot-candles of light for a week prior to harvest as in another set which received only 200 foot-candles. Such variations in light may actually occur under natural conditions.

This preliminary work indicated the importance of the amount of light in vitamin C synthesis. It was necessary to study the effects of light intensity under natural conditions. Concurrently, two lots of tomato plans were grown, one with full exposure to summer sunshine and the other under a muslin shade which reduced the illumination by about 75 percent (fig. 7).

The shaded plants produced fruit very much lower in vitamin C than the plants grown in the sunshine. Transferring the plants from sunshine to shade 2 weeks before harvest resulted in vitamin C values equivalent to those obtained with plants grown continuously in the shade. Transferring plants from shade to sunshine resulted in a comparable increase in the vitamin C.

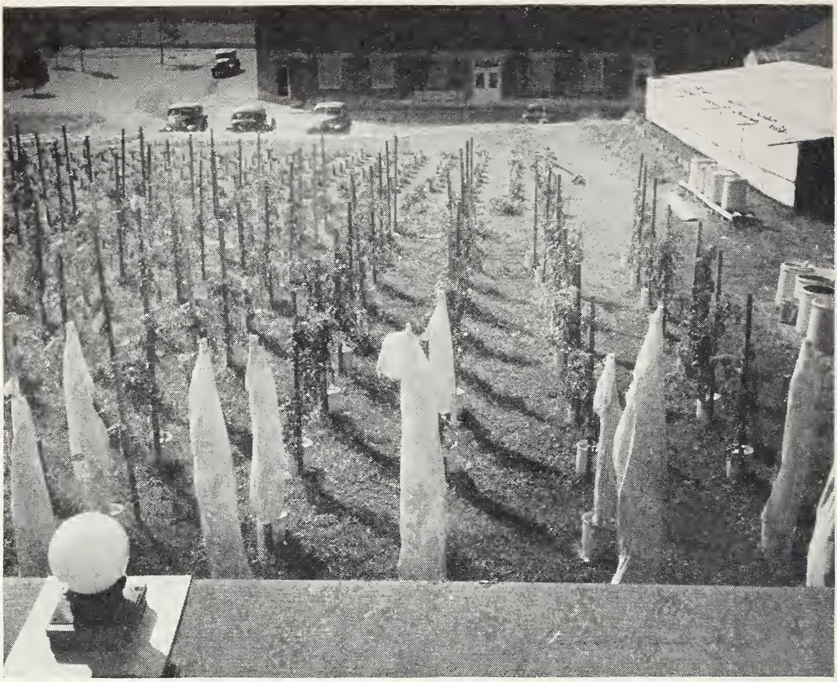


Figure 7.—Some of these tomato plants are shaded with muslin cloth, some are exposed to the full summer sunshine in experiments to determine the effect of light intensity on the vitamin C content of tomatoes. Only the leaves of some plants are shaded; only the fruit of others. Experiments of this kind have indicated that shading the individual fruits for 2 or 3 weeks before harvest causes a decrease in vitamin value.

These experiments showed clearly that the amount of illumination on the individual fruits was the deciding factor. Shading the individual fruits was just as effective as shading the entire plant, whereas shading the leaves produced no effect when individual fruits were not shaded.

In carrying these studies to the field, special light integrators (see fig. 1) were used to measure the amount of illumination received at a field location day by day during the growing season. Field experiments using the instruments produced data consistent with the observations made under controlled conditions.

During several years' study the Cornell School of Nutrition found wide variations in the vitamin C content of commercial brands of tomato juice. These findings raised the question whether the variations were associated with differences in the original fresh material or were the result of canning procedures. The Plant, Soil, and Nutrition Laboratory, in connection with its program on tomatoes, conducted a cooperative study with the Cornell School of Nutrition and the New York Agricultural Experiment Station at Geneva, N. Y., to determine this point.

In the experiment, the vitamin C content of the tomatoes was followed step by step from harvesting in the field, through packing and transportation and the handling of the fruit at the canneries, up to the trimming line. The experimenters at Geneva followed the vitamin content of the tomatoes through the canning procedure, varying their techniques experimentally, and then studied it during storage in the can. The conclusion reached from this study was that the major share of the variations found in canned tomato juice on the market may be traced to variations in the vitamin C content of the original fresh tomatoes.

The question may be asked, "What is the practical use of this information?" It is true that a farmer cannot do anything about the amount of sunlight to which his fields may be exposed. The information obtained from such investigations, however, helps the scientist to define the problem. For example, some varieties of tomatoes are known to be richer in vitamin C than others, but even these varieties may be relatively low in vitamin C when grown under certain climatic conditions. In selecting varieties for breeding programs, the particular location where the tomatoes are to be grown should be considered. It may be possible to develop varieties that will be rich in vitamin C even when grown at locations with limited illumination. At least the background of information now available should help by giving a basis for judicious selection of tomato varieties for any set of climatic conditions.

Figure 8 shows some of the steps in vitamin C analysis.

INFLUENCE OF VARIETY ON NUTRITIVE VALUE

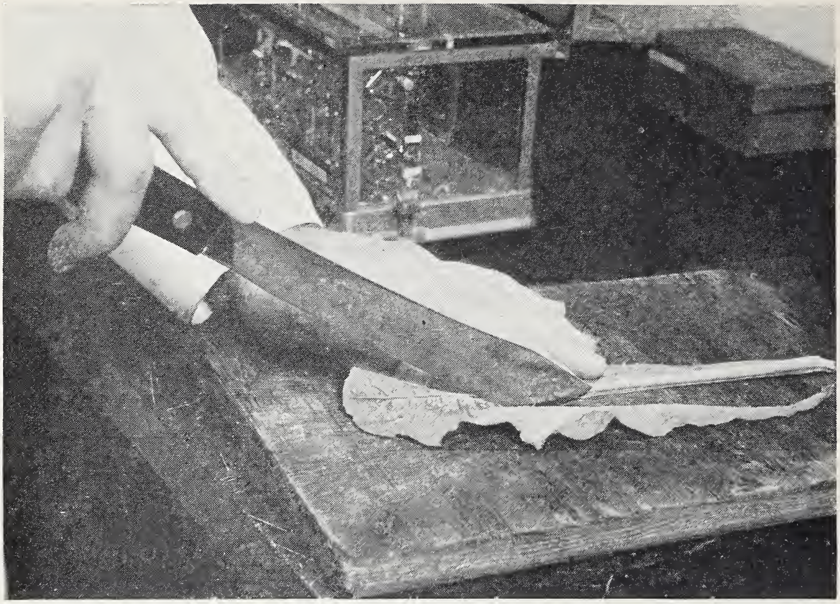
It has long been known that different varieties of plants vary in their appearance and in the flavor of their fruit. Are some varieties richer in particular nutritional constituents than others? In seeking an answer, the nutritive values of a number of varieties produced under the same conditions of climate and soil must be determined. Even after a variety of high nutritive value is selected, the research scientist is not satisfied. He assumes that if existing varieties differ in nutritive value, new and better varieties can be produced by breeding.

Inheritance may play an important part in determining the level of the various nutritive constituents in the plant. Since cultural practices and environmental conditions during the growing season are also important, the feasibility of a breeding program depends on the relative importance of genetic differences as compared with environmental factors.

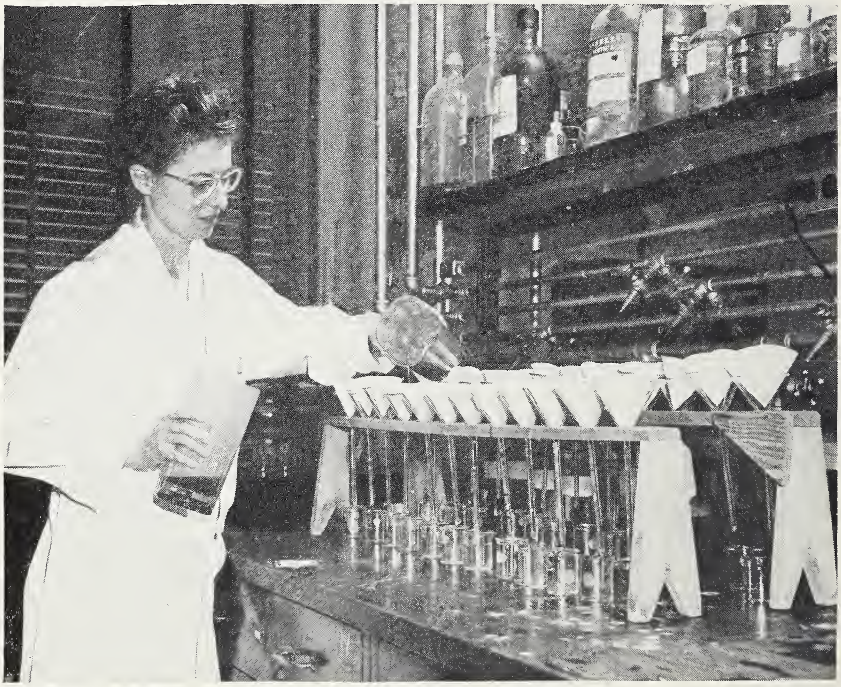
The selection of a plant on the basis of nutritive value is not enough—it must also have commercial possibilities. In other words, it must be disease-resistant, yield abundantly, and have marketable qualities. In attempting to select food crops on the basis of their nutritive value, therefore, we must recognize that the nutritive constituents are merely one of many factors which the plant breeder continually considers in his selection program.

The Plant, Soil, and Nutrition Laboratory has not undertaken breeding work, nor is it equipped to do so. It is, nevertheless, very much interested in the possibility of selecting the most nutritious strains from among those that are available or that can be developed. Such a program is of vital importance.

Let us say, for example, that the vitamin C content of our average potato crop could be increased by selecting varieties approximately twice as high in vitamin C as those now generally available. Assuming that potatoes average about 8 milligrams of vitamin C per 100 grams of fresh weight, the doubling of this value would result in the production of approximately a thousand additional tons of vitamin C each year. This would represent a net gain in nutrition, since, presumably, the new strain would be no more expensive than the old, nor should it be any more difficult to produce. The cheapest factory for vitamin production is still nature's factory.

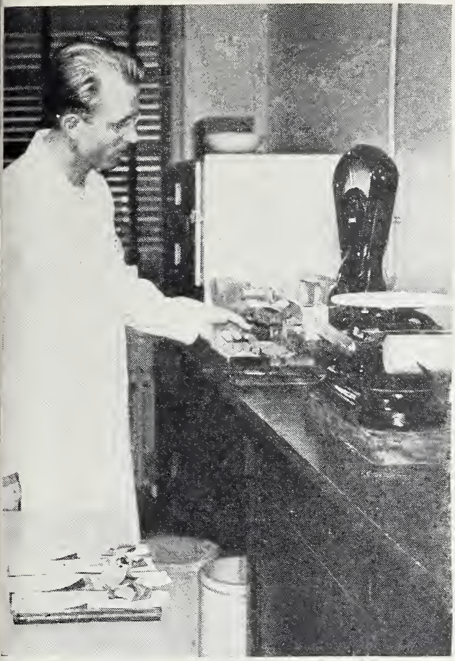


1. Removing the midrib of the turnip leaf preparatory to sampling.

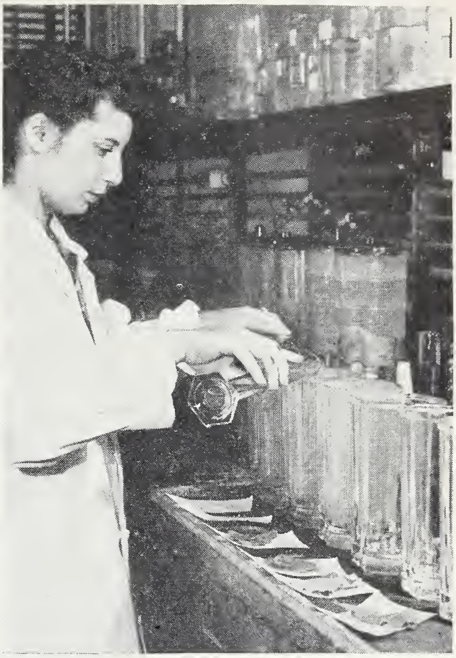


4. The ground material is filtered out of the acid to obtain a clear acid extract.

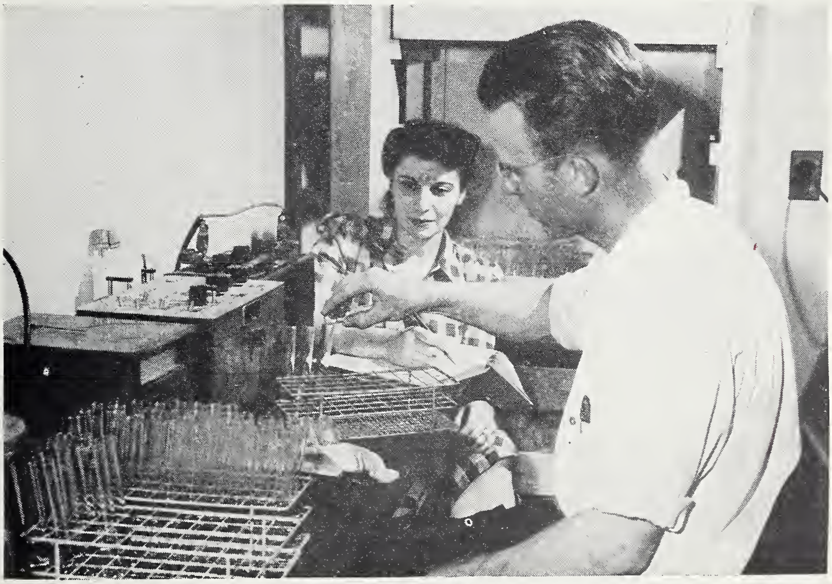
FIGURE 8.—ANALYZI



2. The leaf samples are weighed rapidly and carefully; each leaf is analyzed individually.



3. Placing the samples in high-speed blenders for extracting in acid.



5. Analyzing a portion of the extract for vitamin content.

NIP LEAF FOR VITAMIN C.

The laboratory has therefore initiated cooperative work with several institutions where plant breeding is already under way. The work with potatoes and wheat will serve as examples of this program.

Breeding Potatoes for Vitamin C

Potatoes are usually considered a much poorer source of vitamin C than the citrus fruits or tomatoes, but because they are consumed in such large quantities they contribute a very appreciable percentage of the total vitamin C in the national diet. Recent figures of the Bureau of Human Nutrition and Home Economics indicate that potatoes as purchased furnish about one-third of the vitamin C in our national diet, about as much as the citrus fruits. The availability of commercial varieties of potatoes higher in vitamin C content than those now in production is obviously desirable.

The laboratory has begun investigations to determine the feasibility of a breeding program to increase the vitamin C content of potatoes. First, the specific influences of such factors as time of harvest, cultural practices, where grown, and storage conditions had to be determined. The possible effects of storage conditions are of particular importance, since most potatoes are stored for an appreciable period before being eaten and the vitamin C content of potatoes is known to decrease rapidly during storage.

Studies to date indicate that the vitamin C content of the tubers increases during the growing season until the vines are nearly mature. The location and the season at which the potatoes are grown both affect the vitamin level. After maturity the vitamin content decreases rapidly, whether the potatoes remain in the soil or are stored.

Storage temperatures have a marked influence on the rate of decrease of ascorbic acid (vitamin C). Shifting the potatoes from one storage temperature to another markedly affects the vitamin content, particularly during the early part of the storage period. Potatoes that have been stored at 70° F. for a short time after harvest may increase in vitamin C content temporarily after being transferred to storage at 40°. This increase is followed, however, by a very rapid decrease, so that after a few weeks these potatoes will be lower in vitamin content than those stored continuously at 70°.

These results indicate that great care must be taken in selecting and handling samples for varietal comparisons. Varieties that mature early may have lost an appreciable amount of their vitamin C by the time they are compared with late-maturing varieties when the latter are ready to harvest. If the samples to be analyzed are subject to different conditions before analysis, erroneous results may be obtained.

In spite of all these variables that influence the vitamin content of a given variety, the preliminary results have indicated that varietal differences of considerable magnitude do exist. Some varieties are more than twice as high in vitamin C as others at the time of maturity and tend to remain higher through storage at a given temperature. The magnitude of the varietal differences, therefore, is sufficiently great to indicate the feasibility of breeding for high vitamin content.

The preliminary work indicates that comparisons of varieties and strains should be made either at the exact time of maturity of ecah variety in the field or after a given length of storage at a specific temperature.

Increasing Thiamine in Wheat

With the cooperation of Cornell University and the Bureau of Plant Industry, Soils, and Agricultural Engineering of the United States Department of Agriculture, several thousand samples of wheat have been obtained that represent various strains and varieties grown throughout the United States. Samples have come also from many different plant breeders.

Approximately 5,000 samples have been analyzed for thiamine (vitamin B_1) (fig. 9). The results show that the location where the crop is produced is the primary factor in determining tthe vitamin content during any given season. There is also considerable variation from one season to another. The results also show that there are distinct varietal differences regardless of location, although these differences are not as great as those produced by differences in locality or season. It is believed that by careful breeding over a period of years, selections of wheat could be made that might be consistently at least 50 percent and perhaps 100 percent higher in thiamine than the parent material.

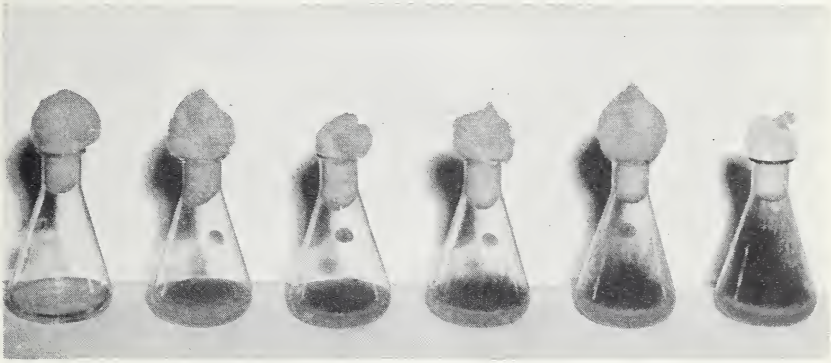


Figure 9.—Microbiological analysis of wheat for thiamine content. The bottles contain samples of wheat differing in thiamine content. The amount of growth made by a fungus which cannot grow without thiamine is a measure of the amount of thiamine in the sample.

It is a question whether such an increase in vitamin content would be worth while (fig. 10). In the production of white flour a great deal of the thiamine is removed in the bran, which is largely used for animal feeds. Is it worth while to undertake a laborious program of breeding to produce wheat rich in a nutrient most of which will not directly reach the consumer? This question is now being given serious consideration.

SOIL IN RELATION TO QUANTITY AND COMPOSITION OF FOOD

Farmers are continually asking, "How can I grow and fertilize my crop to obtain the highest nutritive values?" We do not yet have the answer to this question, but it is through detailed studies of the root environment of plants that the answer will be found.

Such factors as the available mineral supply, water relations, aeration, organic material, soil organisms, topography, and physical characteristics are the important

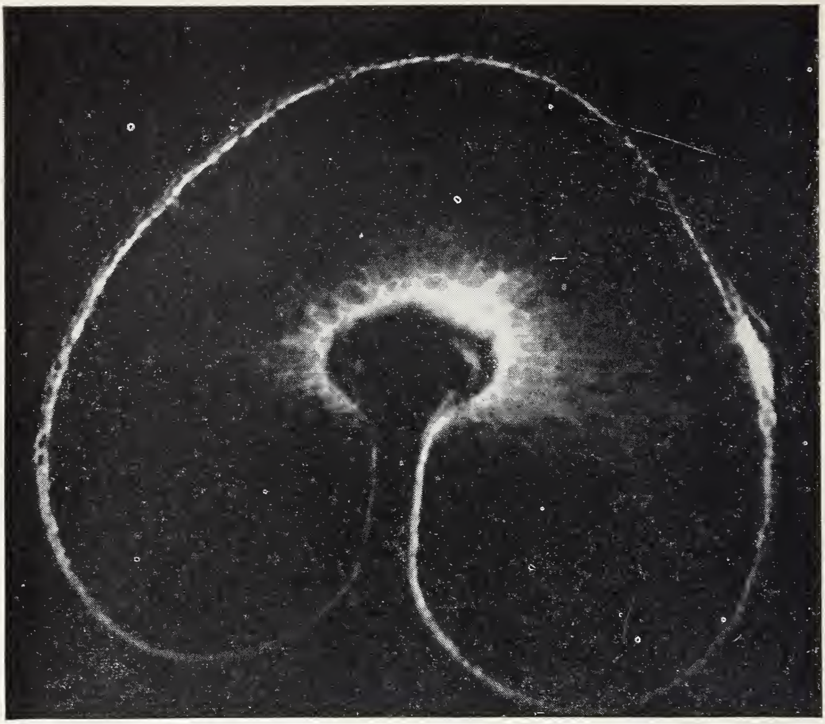


Figure 10.—Distribution of thiamine in a grain of wheat. The thiamine shows white in the photograph, made by a special technique devised at the Plant, Soil, and Nutrition Laboratory. The location of the vitamin in the outer layers (removed as bran) and in the tissues at the base of the grain (removed as germ) explains why so much thiamine is lost in milling.

variables of the soil which influence the plant. All these in turn are influenced by fertilizer and management practices. The soil variables are of great practical importance because we have some control of them and can increase crop production by proper management of the soil.

Soil conditions directly influence the nutritive value of crops. It has been clearly demonstrated that a marked deficiency of a mineral in the soil will lead to a deficiency of that mineral in the crop. In addition we are interested in the effect of soil conditions on constituents other than the minerals. For example, is the quality of the proteins, the availability of carbohydrates, or the concentration of vitamins affected to any considerable extent by the root environment? Perhaps many unknown constituents in crops are essential for highest nutritive value, and their concentration may be influenced by variations in the root environment. All these possibilities call for careful study.

The soil program so far has been concerned primarily with studies of three factors: (1) Mineral supply; (2) moisture supply; and (3) organic matter, the study of which is still in the formative stage. The three approaches are of course closely interrelated.

The effect of mineral supply on the nutritive value of plants is closely connected with the laboratory's crop program. In studying the effect of mineral supply on the absorption of different nutrient elements by plants, leaflets from the tomato experiment in which the effects of mineral supply on vitamin C content of the fruit were examined (p. 9) were analyzed for calcium, magnesium, potassium, and phosphorus. A direct relationship between mineral supply and the mineral concentration in plants was found, as would be expected.

The effects of one element on the absorption of another under these conditions seemed to be unimportant even though statistically significant effects were found. An exception, however, may be the effect of magnesium on phosphorus absorption by the tomato plant. When the calcium content of the nutrient solution was low (2.8 milliequivalents per liter), the phosphorus content of the leaves nearly doubled as magnesium was increased from 2.8 to 19.8 milliequivalents per liter. At the same time potassium in the nutrient solution decreased, but under conditions of a constant potassium supply there was also a correlation between magnesium supply and the phosphorus content of the leaflets.

Another phase of this work included studies of the effects of boron on the absorption of several mineral elements by the tomato leaflet. Some highly significant relationships were observed. For example, an increase in boron supply resulted in significant increases in the manganese, iron, phosphorus, and cobalt contents of the plant tissue. All these elements are important in livestock nutrition. On the other hand, the absorption of a toxic element like molybdenum also increased with increased boron supply. In an alkaline soil with a high molybdenum content the application of large quantities of boron might prove unfortunate.

The content of some elements like magnesium and calcium first increased and then decreased with an increase in boron supply. Several other elements gave quite variable responses to this particular treatment. In all this work so far, both the lowest and the higher levels of boron limited the growth of plants profoundly, so that practical interpretation of the results is not feasible. There is a clear need for work within a narrower range of boron supply, particularly within the range of close correlation between boron supply and crop yield.

It is also desirable to test the effects of boron under normal field conditions. As a contribution to this program, a cooperative experiment was undertaken with the Department of Vegetable Crops of Cornell University. Spinach from a set of fertility plots at the Long Island Vegetable Research Farm was used in a study of the relationships between macronutrient and micronutrient elements. The method was much the same as that used in the solution-culture work described. In the field experiment it was found that an increased supply of boron in association with increased supplies of nitrogen, potash, and calcium resulted in an increased nitrogen content of the spinach. This seemed to be associated, however, with the dry-matter content of the plant. Apparently in this particular experiment, boron was not limiting with respect to spinach. There is need for further study of this important problem.

Another experiment of this type carried out in soil pots was designed to study the effects of liming and the fertility level of the soil on the mineral content of turnips and soybeans. A complete fertilizer was applied to a Dunkirk fine sandy loam at the rates of 1,500 and 2,000 pounds per acre. Lime was applied, raising the pH to 6, 7, and 8.5. Mixtures of micronutrients were added in a manner to permit a study of the factors influencing their absorption by the plant.

It was found that the manganese content of the plant was greatly increased not only by the application of manganese to the soil but also as a result of other fertilizer elements applied. Since pure salts were used, this could not be ascribed to impurities in the nitrogen, phosphorus, or potassium compounds. Liming the soil, however, was very effective in reducing the manganese content of the plant to a level below that present in the control plant. Even when manganese was applied at a high rate, the applications of small amounts of lime limited its absorption by the plant.

Cobalt absorption was also limited by lime applications in these experiments. This would be expected from the close relationship of cobalt to iron and manganese, both of which are influenced to a large extent by lime. Thus in a cooperative experiment with the Department of Agronomy at Cornell University carried out on Mardin soil, it was established that lime had significant effects on the uptake of cobalt, manganese, zinc, and iron by Ladino clover. On the other hand, lime had little effect on the boron, copper, or calcium content of the clover.

The importance of these relationships is emphasized by the extent of areas in this country believed to be deficient in elements such as cobalt. More information is needed on the effect of liming and fertilization on the composition of forages and other crops. Management practices can often prevent or eliminate troubles due to deficiencies, but they may also unknowingly accentuate them under certain conditions.

PHOSPHORUS FERTILIZATION AND THE NUTRITIVE VALUE OF CROPS

Studies in cooperation with Cornell University have dealt with possible changes in the mineral and protein content of forages fertilized with phosphorus at different levels. Ladino clover was grown on each of two soils (Dunkirk silty clay loam and Mardin silt loam) with four levels of phosphorus superimposed on four levels of lime. The four levels of phosphorus were obtained by fertilizing the plots at the rate of 0, 500, 1,000, and 2,000 pounds of 20-percent superphosphate per acre. Lime was applied to the plots to obtain four different levels of acidity (pH 5.0, 5.7, 6.5, and 7.5). Marked responses in yield were obtained at both locations from the phosphorus and lime treatments, but the calcium, phosphorus, and nitrogen contents of the crop were only slightly affected even by the extreme treatments used.

In succeeding experiments, animal-feeding trials have been the important feature of the work. That this approach might produce positive results was indicated by various reports to the effect that fertilization of forages with superphosphate and lime produced crops of superior nutritive value as measured by growth of lambs and rabbits fed the forages, even though the superiority of such fertilized forages was not reflected in their chemical composition.

Sudan grass was grown on a soil that was known to give a response to phosphorus fertilization, half the area being fertilized with this element and half not. The field was weeded by hand to insure an uncontaminated crop. At harvest it was found that yield was 40 percent greater on the fertilized side but that the calcium and phosphorus contents of the two crops were alike and adequate with respect to the needs of sheep. The protein and fiber contents were also very similar in the two forages. In a feeding experiment with two groups of 12 lambs each, in which feed intakes were equalized and wastage avoided, the lambs of both groups maintained their weight but made no growth. Digestion trials also revealed no differences between the two crops.

It was recognized that without growth an adequate test was not provided. Therefore, the experiment was repeated with Canada field peas, a crop certain to be adequate in protein, since a protein deficiency seemed the most probable limiting factor in the Sudan grass. In this experiment, as in the other, the application of phosphorus increased the yield. The crops were similar and adequate in phosphorus content and similar in calcium, protein, fiber, and digestibility. Again, the sheep maintained their weight but made no growth. It became evident from some supplementary trials that the lambs could not eat enough of this hay, even when fed free choice, to provide the energy needed for good growth.

It was decided, therefore, to conduct another experiment in which supplementary energy would be provided by sugar. For this experiment a different area of phosphorus-deficient soil was selected and Ladino clover was used as the forage. Of the crops thus produced, the hay from the fertilized soil contained about 50 percent more phosphorus. However, even the hay from the unfertilized soil contained more of this element than is needed for the optimum growth of lambs. The calcium content of both crops was far in excess of animal needs, as was to be expected. In the feeding trial the hay was supplemented by dextrose to the extent of 18 percent. In the resulting rations, the protein contents were similar and adequate. In this trial, for the first time, both groups made a substantial growth, and the growth was slightly better on the hay from the phosphorus-treated plot.

Additional studies are in progress in cooperation with the North Carolina Agricultural Experiment Station. On the Coastal Plain near Plymouth, N. C., Bladen silt loam soil, which is phosphorus-deficient in terms of crop response, was selected to grow corn, soybeans, and pasture crops to feed sheep. These crops are being grown on plots with and without superphosphate fertilizer. Only such amounts of lime and other fertilizer elements as are believed necessary for a reasonable yield are applied. The crops, combined to make up a balanced ration, furnish the only feed for sheep throughout the year.

Thirty lambs were divided into six groups of five each. Three of the groups were fed the crops from the phosphate-fertilized soil, and three were fed crops from the soil not fertilized with phosphate. Also, lambs in each pen received hay from a different part of the fertilized or unfertilized field. After 70 days on these restricted diets, the lambs fed the "phosphate" hay had gained an average of 0.159 pound per day as compared with 0.182 pound for those fed the "nonphosphate" hay. That this difference was not due to the effect of phosphate on the nutritive value of the hay is shown by the even greater variation among the three groups fed the same hay. Thus, on the phosphate hay the average gains of the five lambs in each pen ranged from 0.109 to 0.194 pound per day. The gains on the nonphosphate hay ranged from 0.160 to 0.260 pound per day.

In the second year of this experiment, the diet of soybeans and hay was supplemented with corn sugar in the same manner as in the experiments at Ithaca. The lambs fed the phosphate hay then gained appreciably more than did those on the nonphosphate hay. This result supported the Ithaca findings. Thus, at both locations an effect of phosphate fertilization was noticed only when the hay was supplemented with sugar in the diet.

Additional work is now being carried on in North Carolina to test the effect of soil fertilization on the progeny of the sheep used in the original feeding trials. Lambs from the ewes on the feeding experiment will be placed on pastures given treatments corresponding to those given the "phosphate" and "nonphosphate" hay and soybeans. The lambs, after being on these pastures during the whole summer season, will be used in further feeding experiments with materials from the same sources.

The experiment will probably continue for a number of years and should be watched with interest, not only for the results obtained but also for the evidence furnished as to the usefulness of these new techniques.

In connection with this study, attention has been given to chemical methods of evaluating forage crops in terms of their content of digestible energy, using lignin and cellulose contents as criteria. Improved techniques for determining these constituents have been developed. Lignin, as determined by the method worked out, has been shown to be undigested in its passage through the intestinal tract and consequently can be used as a reference material for the determination of the digestibility of other dietary constituents by what is known as the lignin-ratio method. Using this method, digestibility of forage crops can be determined without the necessity for quantitative feeding or quantitative collection of feces. Hence this method can be used for animals grazing under natural conditions. It will be possible also, by making a quantitative collection of feces, to measure the feed intake of grazing animals, which will assist greatly in estimating the feeding value of pasture crops.

FUNCTIONS AND REQUIREMENTS OF SPECIFIC NUTRIENTS IN ANIMAL NUTRITION

In none of the experiments with a given crop have all the known nutritive qualities been considered. The magnitude of the task is so great that it is virtually impossible to analyze any given food for all the nutritive constituents, including all the vitamins, minerals, proteins and their constituent amino acids, fats, and carbohydrates. Furthermore, it is probable that there are nutritional essentials not yet identified and that natural foods may vary in nutritive values in ways discoverable only by feeding trials or dietary experiments (fig. 11).

For these reasons, the critical test of the influence of unfamiliar factors on the nutritive value of a given food would be an animal or human nutrition experiment. Experiments with human beings present obvious difficulties, but extensive feeding experiments with animals have been conducted for many years.

In general studies with cattle and sheep, the growth of the animals has long been used to test the effects of pasture-management practices. More recently, this procedure has been popularized under the title "biological assay of soil fertility." The idea seems to have become current, particularly among those unfamiliar with the principles of good animal experimentation, that animal re-

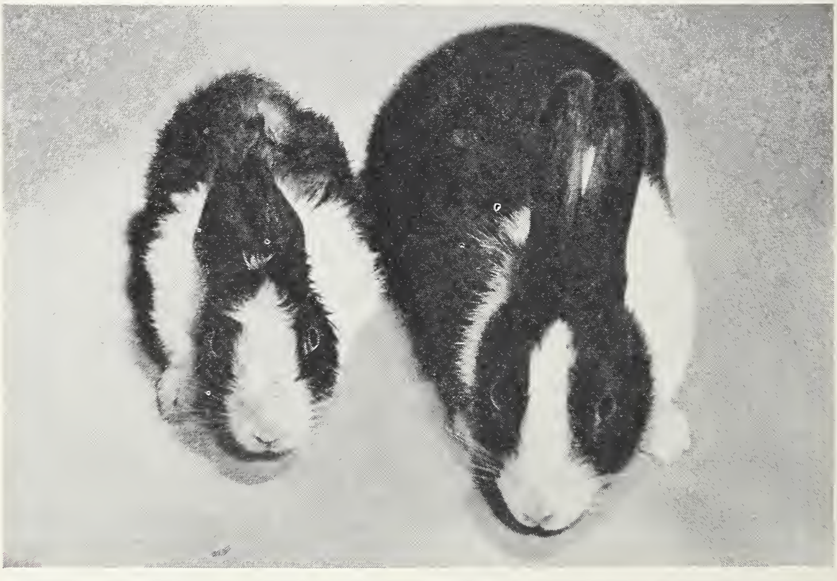


Figure 11.—The rabbit on the left was fed a purified diet that was supposedly nutritionally complete. The one on the right received the same diet with dehydrated alfalfa meal added to it. Dried plant material apparently contains some yet unidentified factor necessary for the growth of rabbits.

sponse can readily indicate the state of fertility of a soil. It is a question, however, whether specific soil treatments are reflected so directly in improved health and performance of men or animals eating the crops produced that the results can be ascribed definitely to the treatment.

The limitations as well as the possibilities of this combined soil-crop-animal experimental technique need to be realized. A feeding experiment must be carefully planned in terms of the nutrient requirements of the animal in question. For example, suppose a particular soil treatment induces a rise in the protein content of the forage from 15 to 20 percent. This increase in protein would not be reflected in any difference in the growth of lambs fed the forage because the optimum protein requirement of sheep is below 15 percent.

A similar situation would be encountered with legumes in the case of calcium and carotene; for, if properly harvested, they always contain these nutrients in amounts far above the needs of herbivorous animals. Again, suppose the forage samples under comparison represent a species containing about 6 percent of protein but with a wide variation in content of some other nutrient, such as phosphorus. The difference in phosphorus content probably would not be detected because the suboptimum protein level would be the limiting factor in both groups. Again, when sheep or rabbits are fed a diet of forage alone, little or no growth may result, so that a critical test is not provided. On the other hand, adding a concentrate as a supplement to induce more rapid growth brings in variables that may cover up any differences existing in the forages themselves.

To the nutrition scientist, a biological assay means a precise experiment. Standardized diets are employed that are adequate in all the known nutritive requirements for the species in question except the factor under test. Where unknown factors are being sought, all the knowns must be present adequately in the test ration. Rigid control is called for all along the line. Feeding trials with farm animals and natural feeds cannot be as rigidly controlled as purified-diet studies with rats or guinea pigs, but the same basic principles of a good nutrition experiment apply.

The recent studies of the laboratory illustrate the factors that need to be taken into consideration to provide an interpretable soil-crop-animal experiment and also the unforeseen complications that may arise.

METHODS FOR THE NUTRITIONAL EVALUATION OF FOODS AND FEEDS

The development of convenient, precise methods for the quantitative determination of specific nutrients has led to rapidly expanding advances in the science of nutrition. The improvement of such methods has not been neglected by this laboratory. The primary objective has been to shorten the time required without sacrificing reliability. The number of analyses for vitamins alone performed so far in this laboratory is conservatively estimated at 50,000, which indicates the desirability of rapid methods.

Progress has been made in the determination of carotene (provitamin A) by rapid chromatographic procedures; in that of vitamin C by a colorimetric procedure; and in that of vitamin B_1 by the fungus-growth method. During the course of these studies the validity of the results has been checked in several instances by comparisons with the results of animal-feeding trials. The need for this precaution was demonstrated in studies of pineapple, in which the concentration of known carotenes was found to be insufficient to account for the vitamin A activity as measured by the rat assay. This led to the discovery that the pineapple contains other carotenoids possessing vitamin A value, whose isolation and identification await further study.

Considerable attention has been given to methods for the determination of minerals in both plant and animal tissues (fig. 12). Such methods are needed not only for the estimation of nutritive value but also in connection with studies of the roles of various minerals in plant and animal physiology. In one study, a procedure was developed for determining 12 of the more important elements with a minimum of time and size of sample that made it possible to make these determinations in duplicate on a 15-gram sample (one-thirtieth of a pound).

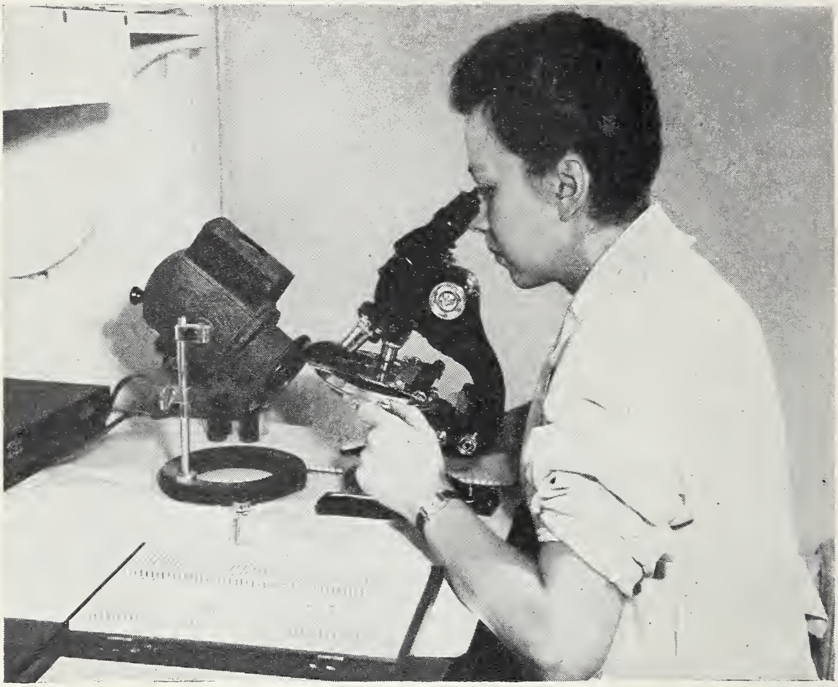


Figure 12.—Studying sections of animal tissue through the microscope.

At the same time various methods of preparing the sample for analysis were studied, and it was concluded that contamination in preparing samples for analysis has been extensive, indicating that many of the values obtained by research workers in the past were erroneously high. New methods adapted to a very small sample of cobalt or manganese and a new colorimetric procedure for determining boron have been developed.

A chemical analysis is a sufficient measure of the nutritive value of some elements. In most cases, however, very little is known about the availability of the element to the animal, and an animal assay must be made. Before an assay can be successfully carried out, the symptoms associated with a deficiency of a given element must be known. A great deal more work along this line is needed. It is particularly important because a knowledge of such symptoms and of the physiological role played by the various elements is an aid in determining the cause of deficiencies found in the field.

The symptoms of most nutritional disorders are nonspecific and vague, and the cause is difficult to determine. This is particularly true in those areas where crops may be low in several elements. Experiments have been carried out designed to (1) discover specific symptoms and tissue changes for use in the study of endemic diseases in which deficiencies of mineral elements might be concerned, and (2) determine quantitative requirements for various elements as a base for assessing the adequacy of the amounts found to be present in specific foods and diets. The elements studied so far have been iron, cobalt, copper, maganese, and zinc. The experimental animals used are the rat, rabbit, and guinea pig.

The need for iron and copper to maintain a normal hemoglobin level in the blood has been confirmed with both the rat and the rabbit. A further symptom of copper deficiency in the rabbit was found. On a low copper diet, there is graying of the normally black hair pigment, often with loss of hair and dermatosis (fig. 13). These symptoms appear under conditions of a mild copper deficiency where the decrease in the level of hemoglobin is small.

A preliminary study of the nutritional adequacy of soybean hay grown in a coastal plain area of North Carolina indicates the value of such basic studies with small animals. The survey work conducted by this laboratory led to the suspicion that forage crops grown in this area are inadequate because of their low content of cobalt and manganese. Chemical analyses of these crops indicated that the copper content was adequate. Nevertheless, symptoms of copper deficiency were noted in rabbits fed hay from this region, which indicates the possibility that the copper may be relatively unavailable to the animal as the hay passes through the digestive tract.

An attempt to produce cobalt deficiency in the rabbit and guinea pig was unsuccessful. The diet used was extremely low in cobalt, containing 0.005 p. p. m., but no deficiency symptoms occurred when it was fed to rabbits for a 46-week period. Since sheep require 5 to 10 times this amount of cobalt and since the livers of the low-cobalt rabbits contain less of this element than those of sheep suffering from cobalt deficiency, apparently there is a difference in requirement. It may be that ruminant animals are the only ones that suffer from soil deficiencies of cobalt.

On the other hand, the rabbit has proved to be a suitable species for the study of manganese deficiency. Deficiency of this element seriously interferes with normal bone development and is strikingly evident in severely deformed front legs (fig. 14). There is a decrease in breaking strength, weight, density, length, and ash content of the leg bones, and microscopic study reveals extensive deviations from normal which are interpreted as suppressed bone formation. A significant decrease in growth and a decrease in the activity of an enzyme of the liver (arginase) and of another enzyme (alkaline phosphatase) of the long bones characterize manganese-deficient rabbits as compared with control animals. These symptoms have been used as a base for assessing the requirement of manganese by the rabbit, which has been found to be approximately 0.3 milligram per day. These findings will make it possible to study the availability of manganese in forages and may prove of value in determining the cause of deficiencies found in the field.

Work with zinc was done with rats. Zinc added to an adequate diet results in anemia and subnormal growth. It was found that additional dietary copper prevents the anemia and that an extract of liver enables normal growth to be made. The factor in liver responsible for this has not been identified. These

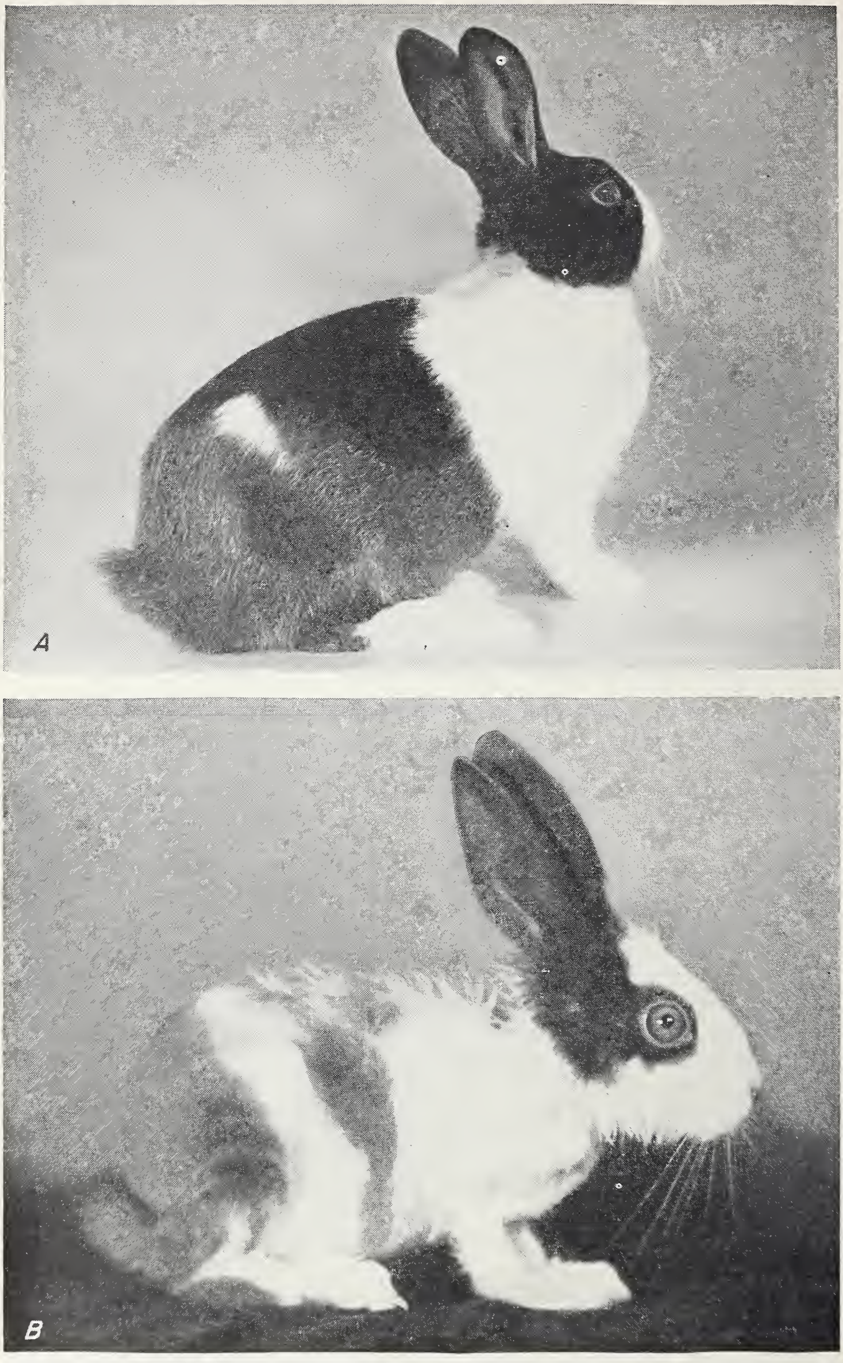


Figure 13.—*A*, Mild copper deficiency in the rabbit's diet causes the development of gray hair; *B*, a more severe deficiency of copper stops growth and makes hair fall out.

studies are of interest because they point to the possibility of important interrelationships between various dietary factors. A given level of an element such as copper may be adequate in one diet and inadequate in another, depending on the zinc content of the diet.

SIGNIFICANCE OF THE LABORATORY PROGRAM AND THE OUTLOOK FOR THE FUTURE

The function of the Plant, Soil, and Nutrition Laboratory is to supply fundamental information on factors in the production of food that affect the nutritive

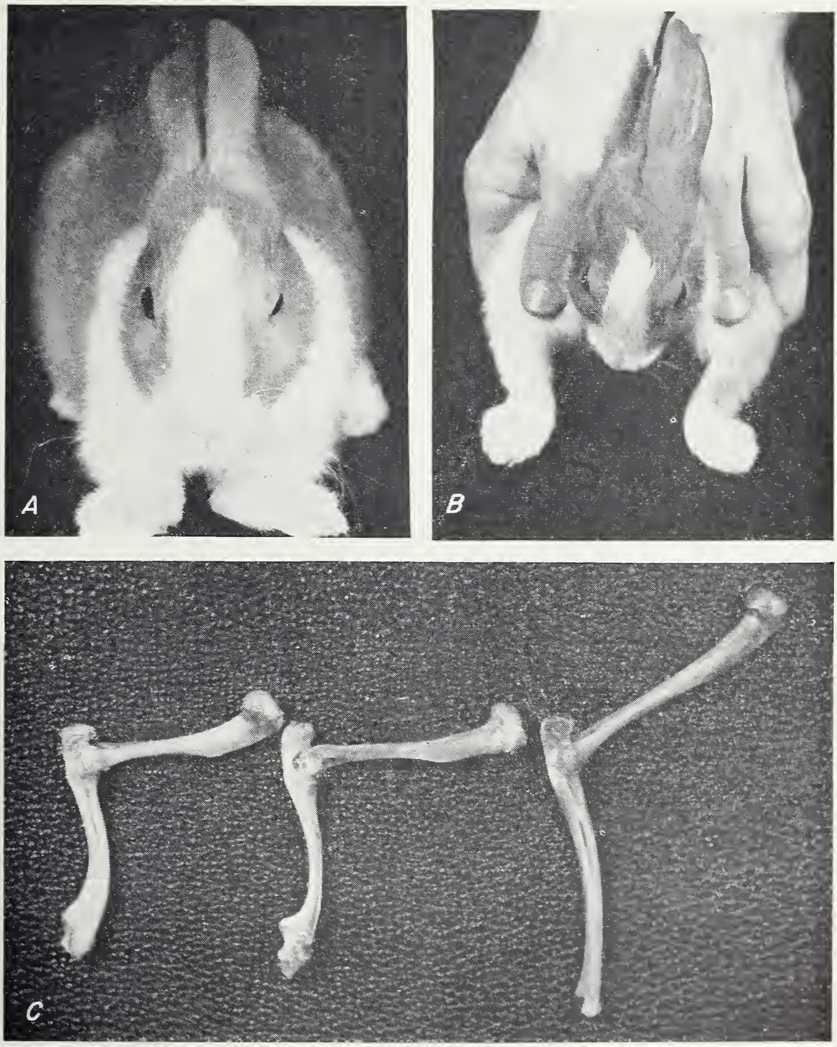


Figure 14.—The striking results of manganese deficiency in the rabbit. *A* and *B*, Two views of the same rabbit, showing malformation of the bones of the front legs as a result of too little manganese in its diet. *C*, The two bones at the left are from the front legs of manganese-deficient rabbits, while that on the right is from a normal rabbit.

value of our basic food crops. Such information is an integral part of any program designed to improve the nutritional value of diets and through better diets the health and well-being of our own people and the peoples of the world.

The unique organization of the laboratory permits it to make a peculiarly significant contribution to this phase of our knowledge of nutrition. As a result of the close cooperation here of scientists in different fields, it is possible to integrate several branches of science for the advancement of the one objective—better nutrition. Soil scientists, for example, as a result of close cooperation with nutritionists, come to understand better the problems of nutrition. Each specialist tends to design his experiments in such a way as to fit the needs of his collaborators.

As the work progresses and our fund of knowledge grows, there will be increasing demand for closely integrated studies that will include the field of human nutrition. This objective, in fact, is foremost in the long-range planning of the laboratory. Studies of the relationship between soil properties and human nutrition problems are difficult to conduct. Our knowledge in the two fields must be much greater than it is today before we shall be able to move ahead rapidly. Inevitably, however, that milestone will be reached.

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